METHOD AND APPARATUS FOR CONTROLLING A DEVICE OR PROCESS WITH VIBRATIONS GENERATED BY TOOTH CLICKS

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/419,393, filed October 17, 2002, and U.S. Provisional Application No. 60/421,633, filed October 25, 2002, under 35 U.S.C. § 119(e).

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for use in controlling a device or process, with particular regard for the needs of disabled persons.

BACKGROUND OF THE INVENTION

There has been a number of alternative technologies developed for controlling a device or process, for use by disabled persons. While these technologies need not be used solely by disabled persons, they have been developed with the particular physical limitations of disabled persons in mind. U.S. Patents 5,233,662 (Christensen 1993) and 5,523,745 (Fortune et al 1996) describe tongue operated apparatus. U.S. Patent 4,865,610 (Muller 1989) describes a mouthpiece into which signals are input by sucking or blowing. U.S. Patent 5,812,978 (Nolan 1998) describes the use of a voice control apparatus.

The use of signals from switches or sensors to control functional electrical stimulation (FES) of paralyzed muscles is known. Use of a shoulder position sensor to control wrist extension via an implanted FES stimulator has been described (Vodovnik, L (1971) "Development of Orthotic Systems using functional electrical stimulation and myo-electric control," Progress Report, University of Ljubljana, prepared for U.S. Dept. of Health Education and Welfare Social and Rehabilitation Service, under contract No. SRS- YUGO 23-68). Use of contact switches placed in the shoe to control FES of the leg muscles has been described (Liberson W.T., Holmquest H.J. Scott D, Dow, M. (1961) "Functional electrotherapy: stimulation of the peroneal nerve synchronized with the swing phase of the gait of hemiplegic patients."

Archives of Physical and Medical Rehabilitation 42: 101-105). Shoulder sensors have also been used to control hand opening and pinch-grip (Peckham, P. K, Marsolais, E. B. & Mortimer, J. T. (1980) J. Hand Surgery, 5,462-469; Petrovsky, J.S. (1985) Hand Control System, EP-145504-A, CA1263446-A, US Patent No. 4,558,704; Peckham, P. H. & Keith, M. W. (1992) "Motor prostheses for restoration of upper extremity function" In "Neural Prostheses: Replacing Motor Function After Disease or Disability" eds.: Stein, R. B., Peckham, P. H. & Popovic, D. B. New York: Oxford University Press. A wrist position sensor has been used to control FES of leg muscles (Prochazka, A. & Wiles, C. M. (1983) "Electrical stimulation of paretic leg muscles in man, allowing feedback-controlled movements to be generated from the wrist" J. Physiol. 343, 20P). A switch mounted on a watch band has been used to trigger FES-evoked pinch-grip (Handa, Y., Itchie, *M.,* Handa, T., Takahashi, K Saito, C., Kameyama, J. & Hoshimiya, N. (1989) "FES-control of multijoint system in the paralysed upper limb." Osaka Int. Workshop on FNS. pp. 91-95.). A multi-component device in which wrist position sensors are used to stimulate FES evoked pinch-grip has also been described (Crago, P. E., Peckham, P. H., Mansour, J. M., Lan, N., Kilgore, K. and Chizeck, H. J. (1991) a, b, c,) "Functional neuromuscular stimulation for restoration of hand grasp." NIH Contract NO1-NS-9-2356 7th, 8th & 9th Progress Reports, June, Septcmber & December, 1991; Crago, P. E., Peckham, P. H. Mansour, J. M., Lan, N., Kilgore, K. and Chizeck, H. J. (1992). "Functional neuromuscular stimulation for restoration of hand grasp." NIH Contract NOl-NS-9-2356. 10th, 11th & 12th Progress Reports, March, June, September, 1992; Peckham, P. H. & Keith, M. W. (1992) "Motor prostheses for restoration of upper extremity function" In: Neural Prostheses: Replacing Motor Function After Disease or Disability, eds.: Stein, R. B., Peckham, P. H. *8c* Popovic, D. B. New York: Oxford University Press). An FES garment is described (Prochazka, A., Wieler, M. Kenwell, Z. & Gauthier M.J. (1996) US Patent No. 5,562,707 in which FES is controlled by signals from proximity detectors which transduce relative motions of an adjacent limb segment such as the hand by monitoring changes in electric or magnetic fields, or changes in the intensity of sound or light transmitted from the adjacent limb segment or changes in the stretching of skin underlying the garment.

SUMMARY OF THE INVENTION

The present invention is an alternative method and apparatus for controlling a device or process, which has been developed primarily with a view to accommodating the needs of disabled persons.

According to one aspect of the present invention there is provided a method for use in controlling a device or process. A first step involves attaching a detector to a person's head. A second step involves detecting mechanical vibrations elicited by sudden contact of upper and lower teeth. A third step involves using the mechanical vibrations to trigger a signal to control operation of a device or process.

According to another aspect of the present invention there is provided an apparatus for use in controlling a device or process, which includes a detector adapted to detect mechanical vibrations elicited by sudden contact of upper and lower teeth. A means is provided for securing the detector to a person's head. A means is provided for transmitting data from the detector to a controller that controls a device or process. The controller may be physically connected to the detector or separated from it.

With the method and apparatus, as described above, a sudden impact between the upper and lower teeth is used as a method of control. Once the basic functioning of the invention is understood there are various features which can be added in order to enhance or ensure the intended functioning of the invention.

In order to ensure signals are not triggered accidentally, the detector may be equipped with an electronic filter and or a logic circuit which screens out incidental teeth contact which may occur during talking or eating.

In order to communicate with the controller, a signal corresponding to the time of contact may be transmitted either by wires or by a wireless transmitter to the controller.

The sensor used in the detector can take a number of forms. Beneficial results have been obtained through the use of an accelerometer or microphone.

The detector may be attached at different positions on a person's head. Beneficial results have been obtained by positioning the detector over the bony mastoid process behind the ear. Beneficial results have also been obtained when the detector overlies the temperomandibular (jaw) joint.

In another embodiment the detector and transmitter could be in the form of a small encapsulated device implanted under the skin.

There are various means by which good contact can be made between the detector and the head of the person. This can be accomplished by providing the detector with an adhesive surface or by taping the detector to the skin or by wearing an elastic headband over said detector or by wearing a springy headpiece of the type used in earphones over said detector or by wearing glasses with springy arms that push said detector onto the skin behind the ear.

There are various technologies which can be used to permit wireless communication of the detector with the controller, such as acoustic or electromagnetic technologies. Data could also simply be transferred from the device to the controller by a cable. The detector component of the transmission system can also be a passive device such as a transponder.

There are various uses which can be made of the apparatus. The controller can be used to cause part of the body of the person wearing the detector to move. The controller can trigger such movement by stimulating muscles, stimulating nerves, controlling an active orthosis or controlling a prosthesis. The device or process being controlled need not be on the person. The device or process can be physically separated from the person wearing the detector. The detector can be used with a transmitter and a controller having a receiver to communicate information or control signals to other people or to electronic systems such as computers. It is possible that any one of a plurality of devices may be triggered according to the temporal pattern or the intensity of the detected vibrations.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings, the drawings are

for the purpose of illustration only and are not intended to in any way limit the scope of the invention to the particular embodiment or embodiments shown, wherein:

FIGURE 1 is a side elevation view of a person wearing an apparatus fabricated in accordance with the teachings of the present invention, with the apparatus being used to operate an electronic stimulator built into a cuff worn on the user's forearm. The detector attached to the side of the user's head is provided with a vibration sensor and an electronic amplifier. Additionally it may be provided with a radio transmitter that may have its own portable power source such as a battery, or it may be in the form of a transponder, receiving power from a remote receiving device. The cuff is provided with electrodes that conduct electrical current into the users body, the purpose of which is to stimulate muscles to produce a movement. The electronic device attached to the cuff receives signals from the detector and uses the information therein contained to trigger the onset of trains of stimulating pulses delivered through the electrodes.

FIGURE 2 is a schematic showing components of one embodiment of the apparatus. The top panel represents the detector and associated circuitry attached to the user's head. The middle panel represents the radio receiver part of the controller, which also incorporates an amplifier and filter that attenuates components of the response of the detector that are unrelated to the desired tooth contact signal (e.g. vibrations elicited by the user's speech). The bottom panel represents controlled devices such as the muscle stimulator in Fig. 1.

FIGURE 3 is a side elevation view of a person wearing an apparatus fabricated in accordance with the teachings of the present invention, with the apparatus being used to control a plurality of devices.

FIGURE 4 is a side elevation view of a person wearing a version of the present invention in which the detector is pressed against the side of the head by a springy band such as is used in earphones.

FIGURE 5 is a side elevation view of a person wearing a version of the present invention in which the detector is pressed against the side of the head by an elastic headband.

FIGURE 6 is a side elevation view of a person wearing a version of the present invention in which the detector is pressed against the side of the head by one of the side-arms of a pair of glasses.

FIGURE 7 is a side elevation view of a person wearing a version of the present invention in which the detector and transmitter are in the form of an encapsulated device implanted under the skin.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred method and associated apparatus for controlling a device or process will now be described with reference to **FIGURES 1** through **7**.

Structure and Relationship of Parts:

Referring to Fig. 1, apparatus 10 includes a detector 20 which is secured to a person's head 22 by adhesive, adhesive tape or other suitable means. It should be noted that the preferred positioning of detector 20 is over a bony mastoid process 28 behind the person's ear 30 or overlying the person's temperomandibular (jaw) joint 32. Detector 20 is adapted to detect mechanical vibrations in head 22 caused by sudden contact of upper teeth 24 and lower teeth 26. Referring to Fig. 2, detector 20 is provided with a vibration sensor 52, such as an accelerometer or a sensitive microphone. It is preferred that a 3-axis accelerometer be used to maximize the selectivity of the detector to vibrations evoked by tooth clicks. In a preferred embodiment, detector 20 is provided with a power source 50, such as a battery or an electronic circuit, which can receive and store power transmitted electromagnetically. However, it will be understood that a passive device, such as a passive transponder may also be used. The preferred version of detector 20 also incorporates an electronic amplifier 54 that amplifies the fluctuations in voltage produced by the vibration sensor 52 in response to vibrations. Preferably, it is also provided with a filter 55 that selectively attenuates signals corresponding to vibrations unrelated to tooth contact. Referring to Fig. 1, Fig. 2 and Fig. 3, there is also included an electronic controller 40, with power source 60 that responds to certain states of the amplified and filtered vibration sensor signals by transmitting commands to one or more controlled devices, such as muscle stimulator cuff 36 in Fig. 1, other devices

and operations exemplified by (but not limited to) 70, 72 and 74 in Fig. 2 and devices, such as: lights 80, computer 82, radio 84, television 86, door opener 88, automobile 90 in Fig. 3. The controller 40 may be physically separate from detector 20, as shown for example in Figs. 1 and 2. In this case, detector 20 may be connected to controller 40 via physical links such as wire or fibre-optic cables. Alternatively, detector 20 may be equipped with a transmitter 56 that transmits the vibration-related signals 34 via an electromagnetic or acoustic communications method to a receiver 62 that is part of controller 40. The received signal is amplified by a signal amplifier 64 and filter 65. It may be further processed by a logic circuit 66 and an output signal generator 68 to control a plurality of devices 70, 72, 74 as shown in Fig. 1 and Fig. 2 and further elaborated in Fig. 3. Illustrated in Fig. 1, is an application relating to muscle stimulation. The person wears a cuff 36 with an in-built control circuit 40 connected to electrodes 38 within the cuff. As illustrated in Fig. 2, the control circuit 40 includes a radio receiver 62, a signal amplifier and filter 64 and 66. Control circuit 40 may also include a logic circuit 66 to maximize the selected recognition of tooth click related components of the signal and to derive command signals accordingly. The command signals are converted to trains of electrical current pulses by signal generator 68, which are transmitted to the muscles through electrodes 38 to activate muscles in the forearm that move the thumb 42 and fingers 44. The diversity of devices which may be controlled is further illustrated in Fig. 3 and includes as examples lights 80, computers 82, radios 84, television sets 86, electro-mechanically operated doors 88 and automobiles 90.

Means are provided to maintain a firm contact between the sensor and the user's head, to ensure good transmission of the vibrations caused by tooth contact to the sensor. Such means are exemplified in Figs. 4, 5 and 6. Fig. 4 shows a spring-loaded headpiece 100, such as those used in earphones. Fig. 5 shows an elastic headband 110. Fig. 6 shows the detector 20 attached to a pair of spectacles 120 having springy arms. Figs. 4, 5 and 6 are examples of three means of fixation, but it is understood that fixation is not limited to these means.

Operation:

The user dons the apparatus which in the preferred embodiment of Fig. 1 comprises the detector 20 and cuff 36 which includes controller 40 and electrodes 38. When power is switched on, either by a manual switch, or by a contact built into the apparatus, the user then controls the stimulator 40 by clicking his or her upper teeth 24 and lower teeth 26 together. Detector 20 and controller 40 respond to the vibrations elicited by the sharp contact between the teeth. The size and/or temporal features of the signals can be used to select between devices or operations. In the preferred embodiment of Fig. 1 successive tooth clicks are used as triggers to electrodes 38 which stimulate muscles to alternatively open and close thumb 42 and fingers 44 of the hand.

Variations:

As shown in Fig. 3, the device controlled can be a computer 82 or a plurality of other controlled devices 80, 84, 86, 88, 90. Other examples of coding to select between a plurality of devices or operations include double-clicks, multiple clicks, variable-intervals between clicks, and clicks of different amplitudes. Detector 20 could be used to operate a communications device in which coded information is transmitted from the user to another person or persons, i.e. telecommunication. In yet another embodiment the detector 20 and transmitter 56 are in the form of a small encapsulated device implanted under the skin 130 in the vicinity of the skull or tempero-mandibular joint, Fig. 7.

Cautionary Warnings:

Frequent sharp impact between the upper and lower teeth could eventually cause dental problems. Users should learn to generate minimal amplitude tooth clicks compatible with reliable detection by the apparatus.